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NASTRAN Modifications for Recovering Strains and Curvatures

BY

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16. Abstract
Modifications to the NASTRAN structural analysis computer program are described which allow the recovery of strain and curvature data for the general two-dimensional elements in addition to the usual stress data. Option features allow the transformation of the strain/curvature (or stress) data to a common coordinate system and representation at the grid points of the structural model rather than at the conventional element center locations. Usage information is provided which will allow present users of NASTRAN to easily utilize the new capability.

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INTRODUCTION

The Lewis Modifications Project has two basic objectives:

1. Produce strain and curvature values for the general two-dimensional elements (TRIA1, TRIA2, QUAD1 and QUAD2) as an alternative to the currently produced stress values.

2. Transform the strain/curvature (or stress) values to a "material" coordinate system and interpolate to the grid points to which the elements are connected.

For the purpose of this project, the term strain/curvature means the quantities defined by

$$\varepsilon_x = \frac{\partial u}{\partial x} \quad , \quad \varepsilon_y = \frac{\partial v}{\partial y} \quad , \quad \gamma_{xy} = \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} \; ,$$

$$\chi_x = \frac{\partial^2 w}{\partial x^2} \, , \quad \chi_y = \frac{\partial^2 w}{\partial y^2} \, , \quad \chi_{xy} = 2\,\frac{\partial^2 w}{\partial x \partial y}$$

where {u, v, w} is the displacement vector measured in a local Cartesian rectangular x, y, z coordinate system.

This report describes the programming changes made to implement these objectives and provides usage instructions for the engineer using this new capability.

PROGRAMMING CONSIDERATIONS

All modifications to NASTRAN are upward compatible in the sense that no change will be observed by any user of currently defined Level 15.5 capability.

Part I

Part I consists of program modifications needed to produce strain/curvature values in lieu of stress values for the general two-dimensional elements. This task was accomplished by a modification of routines STRBS1, STRME1, and STRQD2. Mathematically, the stress-strain matrix was replaced by an identity matrix, and thermal effects were removed. Strains resulting from thermal expansion are included in the displacement-related computations. The strains and curvatures are returned by the element routines in the data words that were used for stresses. Then the output quantities are

$$\begin{Bmatrix} \epsilon_x \\ \epsilon_y \\ \gamma_{xy} \end{Bmatrix} = 1.0 \begin{Bmatrix} \sigma_x \\ \sigma_y \\ \sigma_{xy} \end{Bmatrix}_{membrane} + 0.0 \begin{Bmatrix} \sigma_{x1} \\ \sigma_{y1} \\ \sigma_{xy1} \end{Bmatrix}_{bending}$$

and

$$\begin{Bmatrix} \chi_x \\ \chi_y \\ \chi_{xy} \end{Bmatrix} = 0.0 \begin{Bmatrix} \sigma_x \\ \sigma_y \\ \sigma_{xy} \end{Bmatrix}_{membrane} + 1.0 \begin{Bmatrix} \sigma_{x1} \\ \sigma_{y1} \\ \sigma_{xy1} \end{Bmatrix}_{bending}$$

The strain and curvature computations occur only if DIAG 23 has been turned on by the user. Otherwise, the modified code has no effect and the usual stresses are output. The output formats were not changed; interpretation of the output is simply accomplished by direct correlation with the DMAP sequence utilized; therefore, no work was required in any other module.

Part II

Part II consists of program modifications needed to transform the strain/curvature (or stress) values for the elements to a common "material" coordinate system and then interpolate to the grid points to which the elements are connected. A number of minor modifications to existing modules and a new module (CURV) were required to accomplish this task. These will be described in some detail in the sections that follow.

IFP Modifications

The MAT1 and MAT2 cards were modified to allow the inclusion of a coordinate system reference identification number. For the MAT1 card, MPT now has 12 entries, the twelfth one of which is a non-negative integer coordinate system reference identification number. For the MAT2 card, a new third continuation card holds the 17th data item, which means the same thing as the 12th entry on the MAT1 card.

Material Subroutine Modifications

The MPT data block contains the coordinate system reference identification number. No functional modification to the material property processing routine PREMAT was necessary. No change is necessary for any module which does not desire to use the new data item on the MAT1 and MAT cards.

XMPLBD Modifications

A new entry was added for the new module.

Module Name: CURV

Subroutine Name: CURV

MPL Properties:

Inputs - 6

Outputs - 2

Scratch - 4

Parameters - 3

1 - Integer, default = 0
2 - Integer, default = 0
3 - Integer, default = 0

CURV

A new functional module, CURV, produces strain/curvature (or stress) data at the element grid point locations. A DMAP Alter is used by the user at execution time to invoke this module. The MPL characteristics follow.

Input Data Blocks

1	ØES1	ØFP Element strain/curvature (or stress) table
2	MPT	Material Properties Table
3	CSTM	Coordinate System Transformation Matrices
4	EST	Element Summary Table
5	SIL	Scalar Index List
6	GPL	Grid Point List

Output Data Blocks

1	ØES1M	ØFP Element Strain/Curvature (or stress) Table in Material Coordinates
2	ØES1G	ØFP Grid Point Strain/Curvature (or stress) Table

Note: If DIAG 23 is on, strain/curvature values are computed; otherwise, stresses are generated.

Scratch Data Blocks

1	SCRATCH1	used to hold various lists and tables during the execution of the module.
2	SCRATCH2	
3	SCRATCH3	
4	SCRATCH4	

Parameters

1 Integer, Input, default = 0, Output option flag

- 0 - pass thru the print/punch/plot device code from ØES1 to ØES1G
- ≠0 - use value for ØES1G output device code

2 Integer, default = 0, Processing option flag

- 0 - generate both ØES1G and ØES1M
- 1 - generate only ØES1M

3 Integer, default = 0, Number of interpolation points

- 0 - use all elements in the interpolation
- ≠0 - use value to determine and use closest elements in the interpolation.

CURV Module Data Processing Operations

Each subcase is processed independently of all other subcases, one at a time, until the ØES1 data block is exhausted. For each subcase, two phases of processing occur as described below in summary and later in detail. Either stresses or strain/curvatures are computed according to the content of ØES1. A logic flow chart of the CURV module is shown in Figure 1.

CURV Phase 1 - Data collection and transformation to material coordinates

Several tasks occur during Phase 1, some of which only occur if P2=0.

1. Build an abbreviated subset of the EST data block (called ESTX) containing all elements of potential interest. The order will be that of the ØES1 data block in order to simplify subsequent processing.

Elements not selected for output in case control for a particular subcase, while they will be placed on ESTX, will not be used for that subcase. Note that, as in the case of element stresses, strain/curvatures will only be produced for elements selected in case control, usually via STRESS=ALL.

2. Build a preliminary table of independent points consisting of the center locations of the elements contained on ESTX. The final table is generated after the coordinate system matrices are loaded into core.

3. Build a preliminary table of dependent points consisting of the locations of all grid points to which elements on ESTX are connected. The final table is generated later when coordinate system information is available and after external grid point identifications are computed.

4. Build a list of MCSIDs which are present on ESTX. Write this list onto SCRATCH1 for subsequent use.

5. Transform the strain/curvature (or stress) data to the material coordinate system. This data is written on data block ØES1M for subsequent processing by module ØFP. During this task, the final lists of independent and dependent points are generated.

CURV Phase 2 - Projection and interpolation

For each material coordinate system of interest, the following tasks are carried out:

1. Collect the element center locations (independent points).

2. Collect the unique set of connection point locations (dependent points). All location data is expressed in basic coordinates.

3. Convert all location coordinates to a "local" system and select the appropriate mapping projection. Scale the mapping variables consistently.

4. Form the required entry lists and call the SSPLIN routine to produce the interpolation transformation matrix G as described in P.M. Section 3.4.85 for each dependent point.

5. Transform the strain/curvature (or stress) vectors from the element centers to the grid points.

6. Recompute invariants.

7. Generate the ØFP data block ØES1G for subsequent printing and/or punching. The data is sorted on grid point ID.

The geometry being processed in shown schematically in Figure 2. Detailed programming descriptions of these steps are presented in the remainder of this section.

Phase 1 - Step 1

The abbreviated EST (ESTX) consists of one or more records (one record per element type) of a single word containing the element type code followed by several groups of 11 (for TRIAi elements) or 14 (for QUADi elements) words as follows:

	Word	Symbol	Item
	1	ELTYPE	Element Type code
group of 11 or 14 words repeats for each element of the specified type	2	EID	Element ID
	3	MCSID	Material Coordinate System ID
	4-6	x_1, y_1, z_1	Basic location coordinates of connectivity points (3 for triangles, 4 for QUADs)
	7-9	x_2, y_2, z_2	
	10-12	x_3, y_3, z_3	
	13-15 (for QUADs only)	x_4, y_4, z_4	

In order to generate this information, the following tasks are carried out:

a. Read the MPT data block, extracting the material identification number (MID) and the material coordinate system identification number (MCSID) for each MAT1 and MAT2 material. Entries having no MCSID are ignored. This paired list is sorted on MID and written onto SCRATCH1 for future use.

b. The EST data is passed through core. Only element types of interest are examined. Elements referencing materials having no MCSID are ignored. For elements of interest, find the MCSID from the pair list created in task (a).

Phase 1 - Step 2

The preliminary independent point list consists of six words for each element on ESTX as follows:

Word	Symbol	Item
1	MCSID	Material coordinate system identification number
2	0	Will be filled in with coordinate system type code later.
3	EID	Element identification number
4	xc	Center basic location coordinates
5	yc	
6	zc	

Phase 1 - Step 3

The preliminary dependent point list consists of 16 or 20 words for each element on ESTX as follows:

Word	Symbol	Item	
1	MCSID	Material coordinate system identification number	
2	0	Will be filled in with coordinate system type code later.	
3	EID	Element identification number	
4	NPTS	3 for TRIAi elements, 4 for QUADi elements	
5	SILi	SIL for connected point	repeats for each connected point
6	xi	Basic location coordinates	
7	yi		
8	zi		

Phase 1 - Step 4

During generation of ESTX, the entries of the MID - MCSID pair list were flagged when referenced. At this point, the unreferenced items in this list are removed.

Phase 1 - Step 5

The ØES1 and ESTX data blocks are now simultaneously read, element by element. For those entries appearing on both data blocks, the strain/curvature (or stress) data items are transformed to the material coordinate system via subroutine TRANEM. The invariant quantities are recomputed* and the resulting data are written onto ØES1M for subsequent processing by ØFP. As a preprocessing task, once the CSTM data has been read into core, the independent and dependent lists are converted to final form by substituting the coordinate system type code for the second word of each entry. This task is only done if P2=0. As a post-processing task, items not on ØES1M are removed from the point lists.

*See Section 4.87.4.6 of the NASTRAN Programmer's Manual

The transformation matrix U was designed to transform "tensor" components such as stresses. If strains are to be transformed (DIAG 23 is on), then the third component (γ) must first be multiplied by $\frac{1}{2}$. The $(\sigma)_m = U(\sigma)_e$ material components are computed by matrix multiplication. The, if DIAG 23 is on, the "engineering" shear strain is recovered by multiplying the last component by 2.

Phase 2 - Step 1 (phase 2 is done only if P2 = 0)

Pass the independent point table, eliminating any points not associated with MCSID. Since this table has already been reduced to ØES1M size, the resulting subset is exactly the desired data required in Phase 2.

Phase 2 - Step 2

Pass the dependent point table, eliminating any points not associated with MSCID. Collect the unique set of grid point ID's and their corresponding basic location coordinate for subsequent use in Phase 2. This list will be sorted on external grid point ID.

Phase 2 - Step 3

a. Convert both the independent and dependent location coordinates to the local material coordinate system.

$$\vec{r}_{local} = T^T\{E-V\}$$

E - $\vec{r}$ measured in basic coordinate system

V - reference vector obtained from the CSTM data block (words 3-5)

T - transformation matrix obtained from the CSTM data block (words (6-14) stored by row.

See P.M. Section 2.3-33 and 3.4-64 for details.

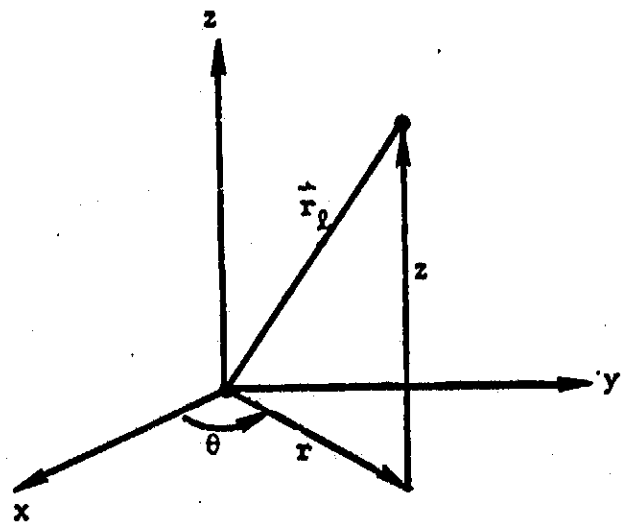
b. Convert dependent and independent location coordinates $\{r_\ell\} = \{x,y,z\}$ to mapping coordinates $\{\rho\} = \{\rho_1,\rho_2,\rho_3\}$ as follows. For rectangular coordinate systems, $\{\rho\} = \{r_\ell\}$. For cylindrical coordinate systems,

$$\rho_1 = r = \sqrt{x^2+y^2}$$

$$\rho_2 = \theta = \begin{cases} \tan^{-1}(y,x), & r > 0 \\ 0, & r = 0 \end{cases} \qquad \text{(in radians)} \quad -\pi < \theta \le +\pi$$

$$\rho_3 = z$$

as shown on the following sketch.



cylindrical

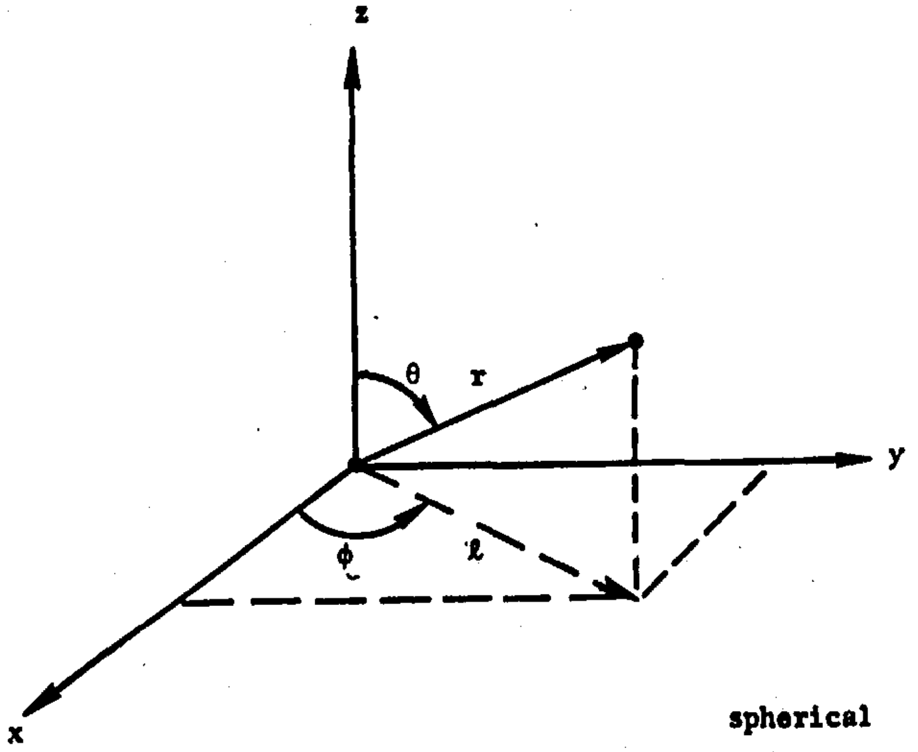
For spherical coordinate systems, $\{\rho\} = \{r, \theta, \phi\}$ where, if we let $\ell = \sqrt{x^2+y^2}$,

$$\rho_1 = r = \sqrt{x^2+y^2+z^2}$$

$$\rho_2 = \underset{\text{(in radians)}}{\theta} = \begin{cases} \tan^{-1}(\ell, z), & r > 0 \\ 0, & r = 0 \end{cases} \qquad 0 \le \theta \le \pi$$

$$\rho_3 = \underset{\text{(in radians)}}{\phi} = \begin{cases} \tan^{-1}(y, x), & \ell > 0 \\ 0, & \ell = 0 \end{cases} \qquad -\pi < \phi \le \pi$$

as shown in the sketch below:



spherical

c. Select the projection based on the independent points. To do this we want to find the mapping coordinate which has the smallest range of values. Define a characteristic length as follows for angular mapping coordinates:

cylindrical: $\bar{\ell}$ = average r

spherical: $\bar{\ell}$ = average r

The projection is selected by finding which coordinate yields
$\min \{x_{max} - x_{min}, y_{max} - y_{min}, z_{max} - z_{min}\}$
for rectangular coordinate systems, $\min \{r_{max} - r_{min}, \bar{\ell}\theta_{max} - \bar{\ell}\theta_{min}, z_{mzx} - z_{min}\}$ for cylindrical coordinate systems, or $\min \{r_{max} - r_{min}, \bar{\ell}\theta_{max} - \bar{\ell}\theta_{min}, \bar{\ell}\phi_{max} - \bar{\ell}\phi_{min}\}$ for spherical coordinate systems.

The resulting mapping surfaces are illustrated (for regular mesh spacing) on the following sketches.

d. The interpolation independent variables are now selected by discarding the selected projection coordinates and scaling both the remaining two mapping coordinates to have the range -1 to +1.

e. The interpolation dependent variables are now arbitrarily reduced and scaled by the same selection and scaling as was used for the independent variables.

The net result of step 2 is two sets of pair lists,

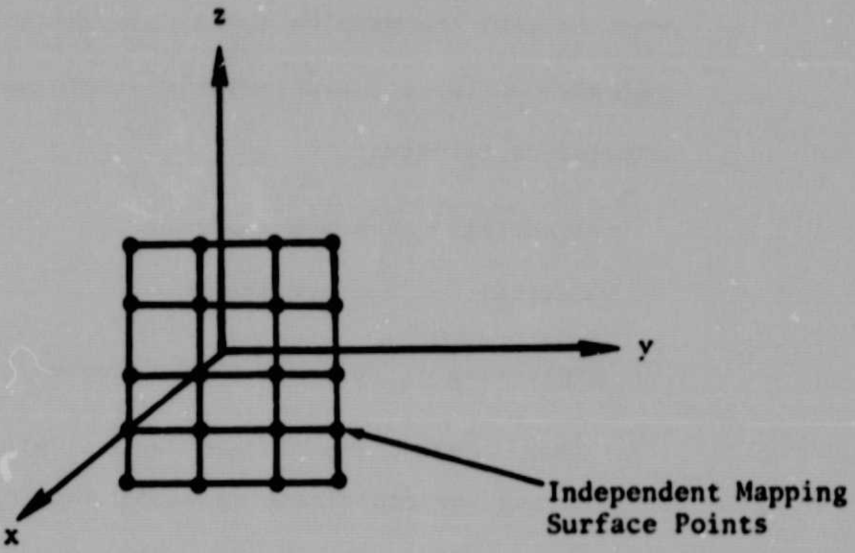
xi, yi, i = 1, Ni

and xd, yd, d = 1, Nd

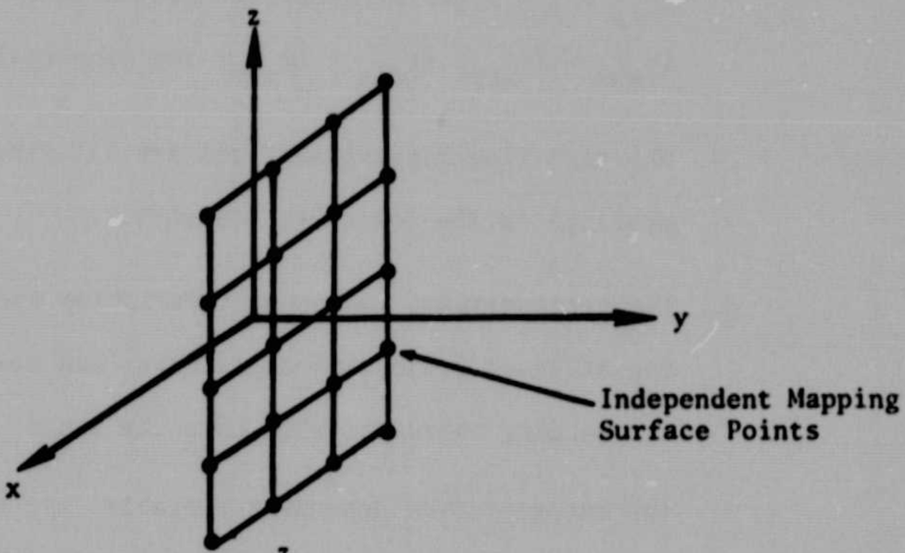
which will now be used in step 4.

Rectangular Mapping Surfaces
(uniformly spaced meshes are shown for convenience)

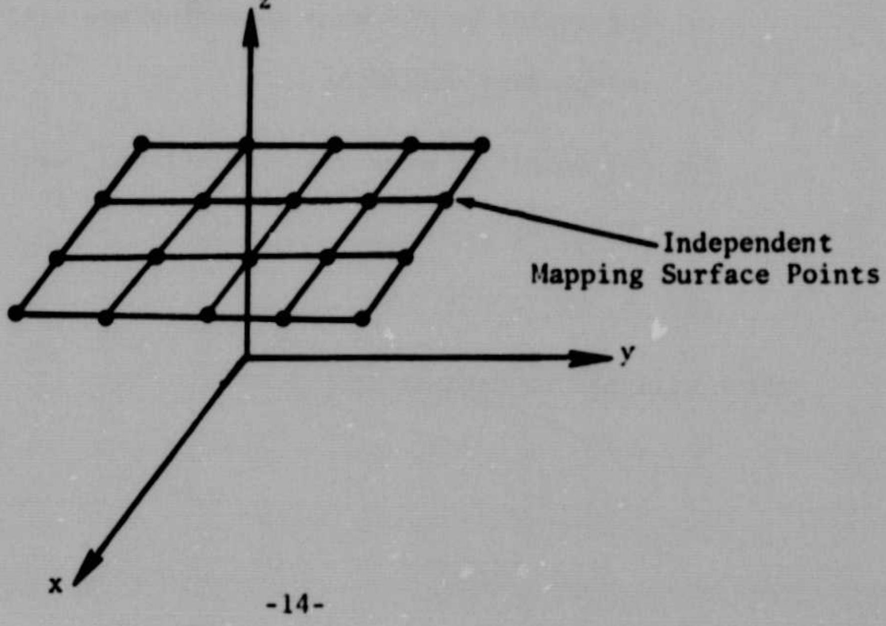
x = const



y = const

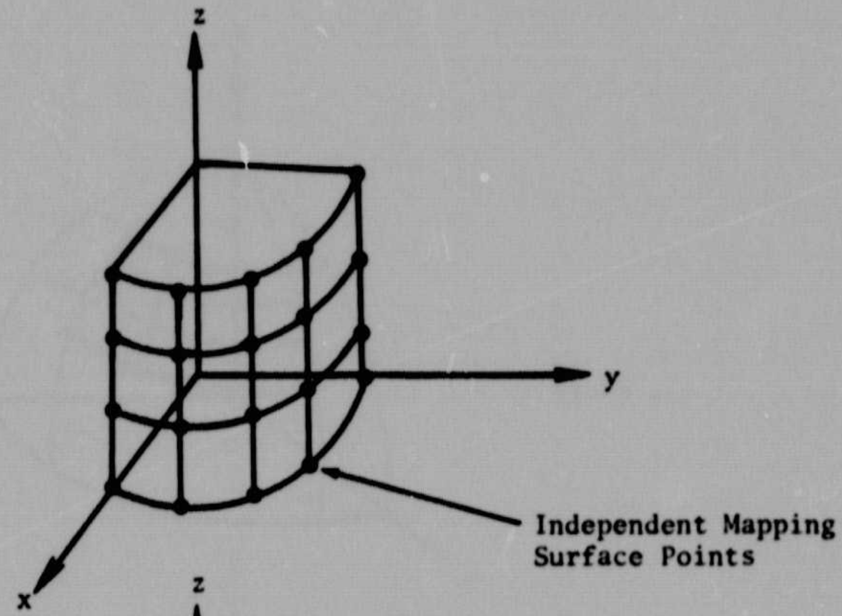


z = const

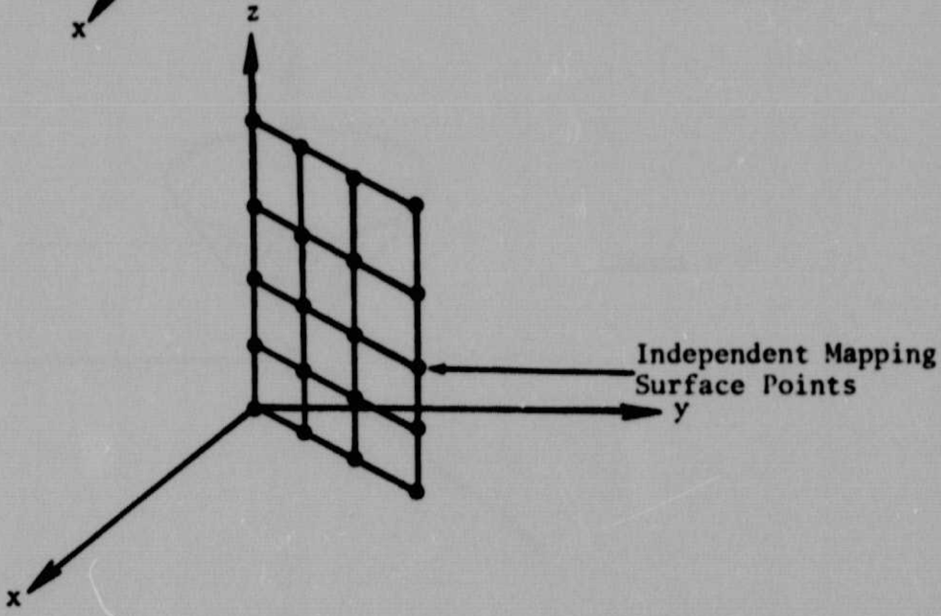


Cylindrical Mapping Surfaces
(uniformly spaced meshes are shown for convenience)

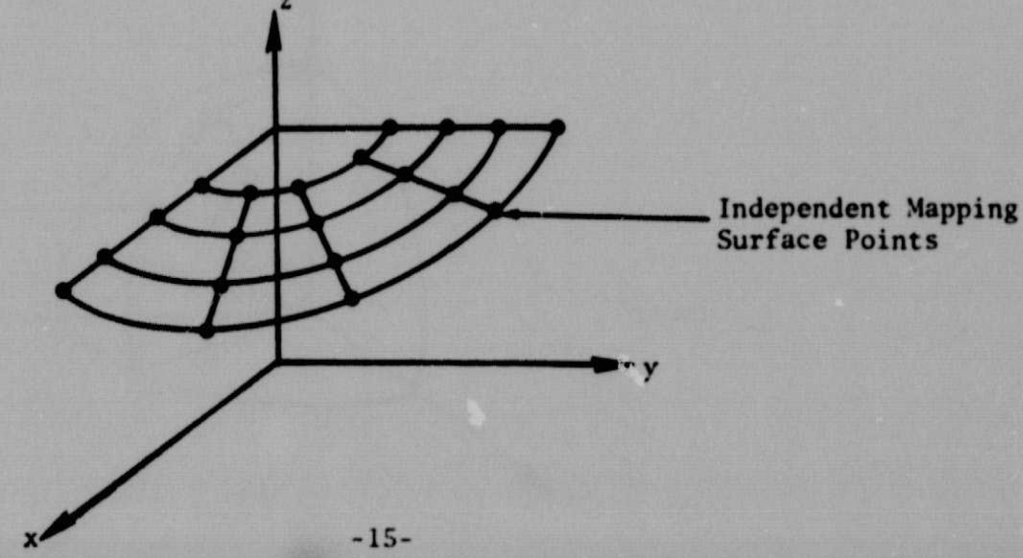
r = const



θ = const

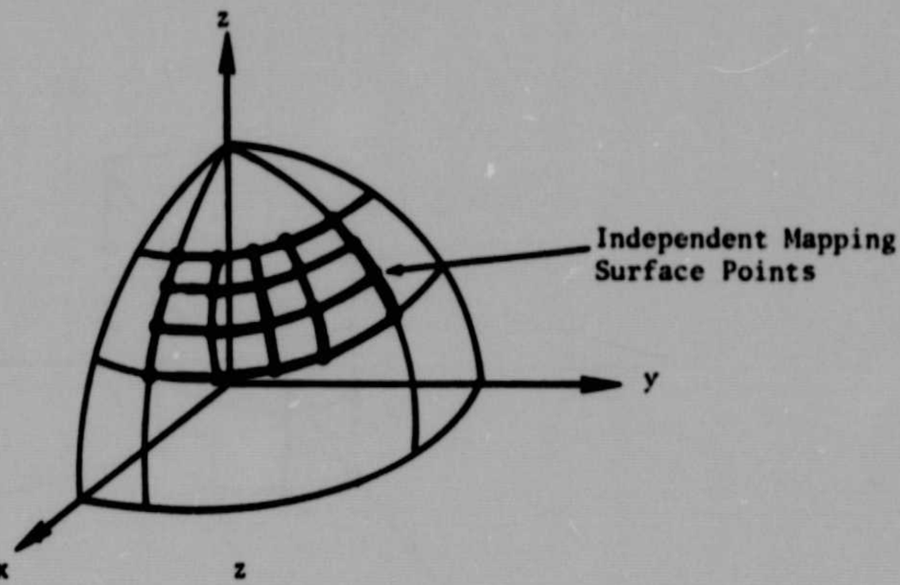


z = const

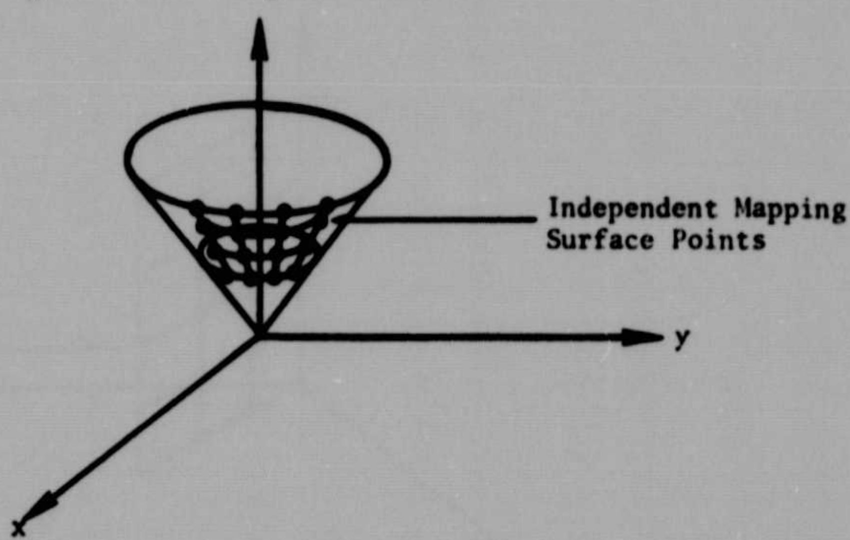


Spherical Mapping Surfaces
(uniformly spaced meshes are shown for convenience)

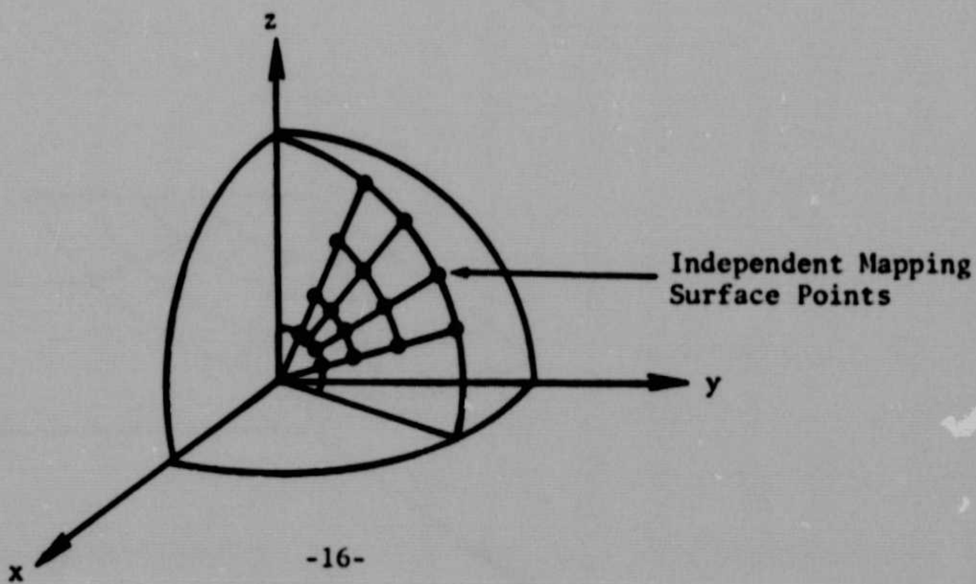
r = const



θ = const



ϕ = const



Phase 2 - Step 4

This step consists of preparing the input data for interpolation, calling the interpolation routine SSPLIN, and handling the resulting G matrix preparatory to carrying out Step 5. If the third parameter is nonzero, its value is used to determine the number of closest independent points for each dependent point; only these points are used in the SSPLIN interpolation. If the third parameter is zero, *all* independent points are used in the SSPLIN interpolation to obtain *all* dependent points. In both cases, the points used are the ones shown on the previous mapping surface sketches.

Phase 2 - Step 5

Read into core the strain/curvature (or stress) data from ØES1M and prepare it in a form suitable for multiplication by the transformation matrix G created in Step 4. Core is assumed to be large enough to hold the entire operation. Call GMATTS to carry out the transformation.

Phase 2 - Step 6

Generate the invariants associated with the strain/curvature (or stress) quantities generated in Step 5 using equations of Section 4.87.4.6 of the NASTRAN Programmer's Manual.

Phase 2 - Step 7

From the data obtained in Steps 5 and 6, generate the ØES1G data block. This data is generated in external grid point sort.

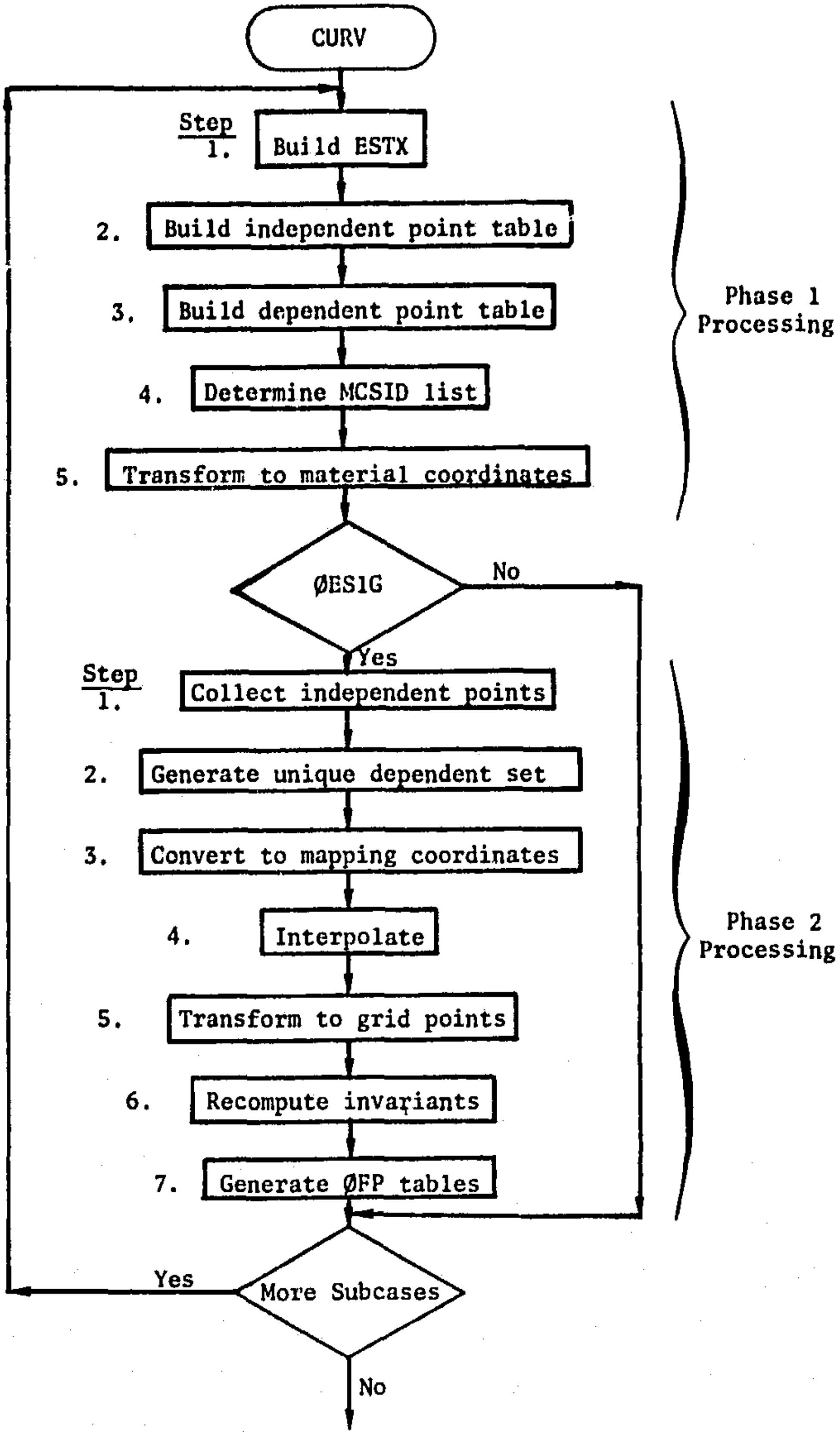
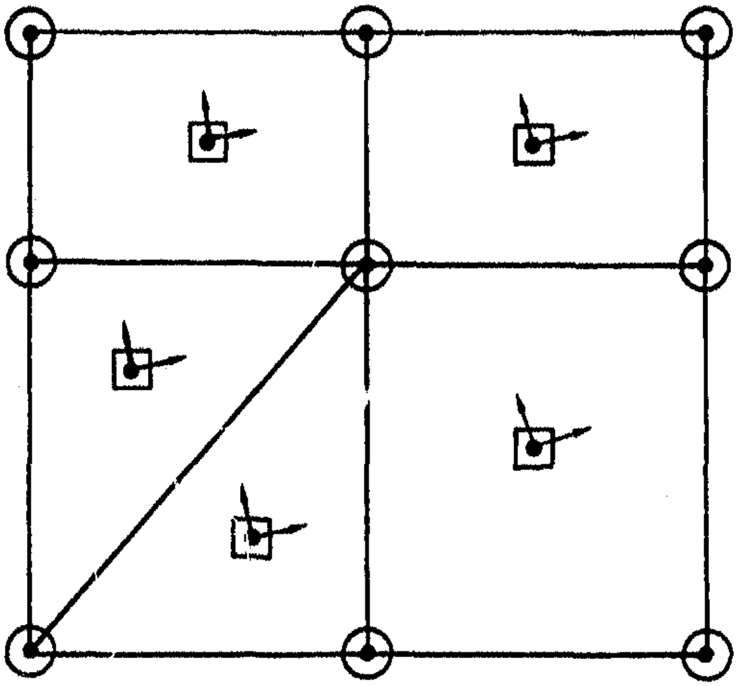


Figure 1. CURV Module Logic Flow Chart



Grid Point Locations (Dependent Points)

Element Center Locations (Independent Points)

Material Coordinate System

Figure 2. Element Geometry

Subroutine TRANEM

Purpose: Computes a transformation matrix U for triangles and quadrilaterals which will convert strain/curvature (or stress) vectors measured in the element coordinate system to a material coordinate system projected on the surface of the element.

$$\begin{Bmatrix} \sigma_x \\ \sigma_y \\ \tau \end{Bmatrix}_{\substack{\text{material} \\ \text{coordinates}}} = [U] \begin{Bmatrix} \sigma_x \\ \sigma_y \\ \tau \end{Bmatrix}_{\substack{\text{element} \\ \text{coordinates}}}$$

Calling Sequence:

```
CALL TRANEM(MCSID,NG,R,ICØMP,U,RC)
```

MCSID - Material coordinate system identification number, input.

NG - 3 for triangles, 4 for quadrilaterals, input.

R - basic coordinate locations of connection points, length=3*NG, input.

ICØMP - 1 if material x-axis is used, 2 if material y-axis is used, output.

U - transformation matrix, length=9, row stored, output.

RC - basic location coordinates of element center, length=3, output.

Requirement: The calling subroutine must call PRETRS.

Method:

1. Compute the element normal:

Triangles - $\vec{n} = \vec{v}_{13} \times \vec{v}_{23}$

$$= (\vec{v}_3 - \vec{v}_1) \times (\vec{v}_3 - \vec{v}_2)$$

Quadrilaterals - $\vec{n} = \vec{v}_{13} \times \vec{v}_{24}$ (definition)

$$= (\vec{v}_3 - \vec{v}_1) \times (\vec{v}_4 - \vec{v}_2)$$

2. Compute the center of the element:

$$\vec{RC} = \frac{1}{NG} \Sigma \vec{R}$$

3. Call TRANS to compute the unit vectors of the material coordinate system MCSID at the center of the element.

4. Select the reference axis:

   If the element normal is not normal to the material coordinate x-axis projection, use the x-axis and set ICØMP=1. Otherwise, use the material coordinate y-axis and set ICØMP=2. The criteria is arbitrarily chosen to be $\vec{n} \cdot \vec{i}_m > 0.4$ for use of the y-axis rather than the x-axis.

5. Compute the sine and cosine of the angle between the selected material coordinate system axis and the element coordinate system x-axis.

6. Generate the transformation matrix U:

$$U_{11} = \cos^2\theta$$
$$U_{12} = \sin^2\theta$$
$$U_{13} = -\sin\theta\cos\theta$$
$$U_{21} = \sin^2\theta$$
$$U_{22} = \cos^2\theta$$
$$U_{23} = \sin\theta\cos\theta$$
$$U_{31} = \sin 2\theta$$
$$U_{32} = -\sin 2\theta$$
$$U_{33} = \cos 2\theta$$

USAGE OF SDR2 AND CURV MODULES

General

There are two basic choices available to the user. First, stresses, strains, or both may be requested. This is controlled by the use of DIAG 23 in modules SDR2 and CURV. Second, the quantities may be computed in three basic ways:

(a) At element centers using an element coordinate system.

(b) At element centers using a material coordinate system.

(c) At grid point locations using a material coordinate system.

All combinations of (a), (b) and (c) are possible. This is controlled by the introduction of the CURV module, the second parameter of the module, and by selection of ØFP inputs in the ALTERs. Item (a) is the usual SDR2 output, (b) is generated during the first phase of CURV, and (c) from the second phase of CURV. Output is controlled by CASE CONTROL (e.g., STRESS (PUNCH)=request) and by the second parameter of CURV.

Data Requirements

The first feature is the ability to request strain/curvature data in lieu of the usual stress data for all TRIA1, TRIA2, QUAD1 and QUAD2 elements selected for output. This feature is selected by turning on DIAG 23 in the Executive Control Deck. No other user data is needed for this feature.

If both stresses and strains are desired for the selected set of elements, the following alter packet may be used. DIAG 23 is not used in the Executive Control Deck.

```
ALTER    121
PARAM    // C,N,SSST / C,N,+23 $
SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDT,,,UGV,EST,/
         ,,,ØES1A,,/ C,N,STATICS $
ØFP      ØES1A,,,,, // $
PARAM    // C,N,SSST / C,N,-23 $
```

For this application, element stresses will be writtn on data block ØES1 and element strain/curvatures will be written on data block ØES1A as a result of the alter.

The second feature provides the user with the ability to output the element strain/curvatures (or stresses) generated according to the preceding discussion for all selected TRIA1, TRIA2, QUAD1 and QUAD2 elements in a material coordinate system at the grid points to which the elements are connected using surface spline interpolation. To use this feature, the following DMAP alter packet must be employed in displacement rigid format number 1, static analysis:

```
ALTER    121
CURV     ØES1,MPT,CSTM,EST,SIL,GPL/ØES1M,ØES1G/C,Y,ØUTØPT=0/C,N,0/C,N,0 $
ØFP      ØES1G,,,,,// $
```

ØES1M, while not subsequently used in the DMAP, must be present as it is used as a scratch file.

The element strain/curvature (or stress) values may also be output in the material coordinate system. In this case, the alter would be

```
ALTER    121
CURV     ØES1,MPT,CSTM,EST,,/ØES1M,/C,Y,ØUTØPT=0/C,N,1/C,N,0 $
ØFP      ØES1M,,,,,// $
```

Both element and grid point related outputs may be obtained for the first CURV alter shown by changing the ØFP call to

```
ØFP     ØES1M,ØES1G,,,,// $
```

DMAP Module Description

The calling sequence for the CURV module is described below:

DMAP Call:

```
CURV    ØES1,MPT,CSTM,EST,SIL,GPL / ØES1M,ØES1G / C,Y,ØUTØPT=0 /
         C,Y,ØPT2=0 / C,Y,ØPT3=0 $
```

Input Data blocks: As described by standard documentation

Note: SIL and GPL may be purged if ØPT2 ≠ 0 .

Output Data Blocks: ØES1M - Element strain/curvatures (or stresses) measured in material coordinates

ØES1G - Grid point strain/curvatures (or stresses)

Note: ØES1G may be purged if ØPT2 ≠ 0 .

Parameters:

ØUTØPT - Integer, Input, default = 0 .

0 = Pass through the Print/Punch/Plot device code from ØES1 to ØES1M and ØES1G.

≠0 - Use value for ØES1M and ØES1G output device code.

ØPT2 - Integer, Input, default = 0 .

0 - Generate both ØES1G and ØES1M

≠0 - Generate only ØES1M

ØPT3 - Integer, Input, default = 0 .

0 - Use all independent points in the interpolation.

≠0 - Use value as the number of "closest" points to use in the interpolation.

The possible output device codes are:

1 = print

4 = punch

5 = print and punch

Output

The case control card STRESS is used to request all of the various kinds of output that are possible. Interpretation is made by examining the values which appear under the heading labeled "FIBRE DISTANCE" as indicated below:

Quantity	Quantities in "FIBRE DISTANCE" printout
1. Element stress in element coordinates	a, b, fibre distances z_1 and z_2
2. Element stress in material coordinates	a. material coordinate system id (real) b. axis code (real) 1.0 = material x-direction chosen 2.0 = material y-direction chosen
3. Grid point stress in material coordinates	a. material coordinate system id (real) b. projection code + 10*N (real) 1.0 = material x-axis is normal to projection 2.0 = material y-axis is normal to projection 3.0 = material z-axis is normal to projection (N is the number of interpolation points used)
4. Element strain/curvatures in element coordinates	a, b, fibre distances z_1 and z_2
5. Element strain/curvatures in material coordinates	a. material coordinate system id (real) b. axis code (real) 1.0 = material x-direction chosen 2.0 = material y-direction chosen
6. Grid point strain/curvatures in material coordinates	a. material coordinate system id (real) b. projection code + 10*N (real) 1.0 = material x-axis is normal to projection 2.0 = material y-axis is normal to projection 3.0 = material z-axis is normal to projection (N is the number of interpolation points used)

REFERENCES

1. Hennrich, C. W. (Ed.), "The NASTRAN Programmer's Manual," NASA SP-223(01), Level 15.5, May 1973.

APPENDICES

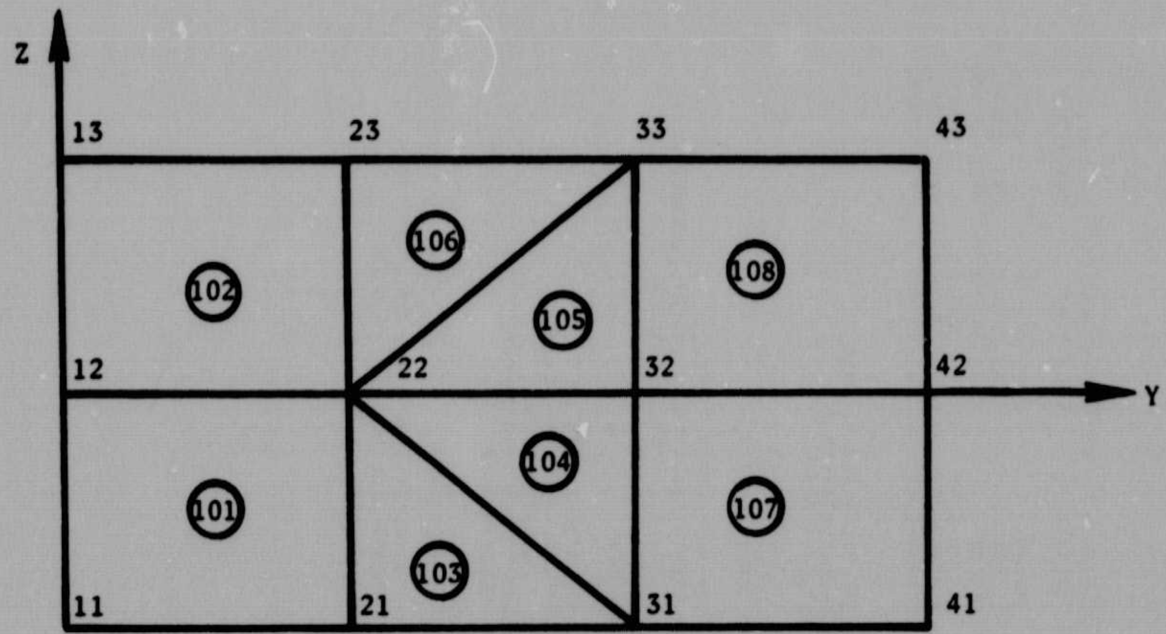
In order to assist the user in using this new capability, a sample problem is presented in Appendix A. In addition, Appendix B presents DMAP ALTER packets which illustrate how the various options may be combined to produce a desired result. The new user is encouraged to study these appendices before attempting to utilize this new capability in his work.

While Rigid Format 1, Static Analysis, was used in both appendices, the new capability described in this report is not restricted by Rigid Format. Any Rigid Format (or DMAP sequence for that matter) which produces real, SØRT1 stress output can be altered to use the new capability. In many cases, only the alter numbers will differ from the material presented herein.

APPENDIX A

SAMPLE PROBLEM

The data deck listing and selected NASTRAN output pages for the small sample problem shown below are presented on the following pages. The notes are keyed to the card numbers on the deck listing.



PRECEDING PAGE BLANK NOT FILMED

```
ID EC296 TESTB $
TIME 5
APP DISP
SOL 1,0
$
$       DATA BLK        QUANTITY        LOCATION        REFERENCE
$
$       OES1            STRESS          ELT. CENTER     ELT. COORD.
$       OES1M           STRESS          ELT. CENTER     MAT. COORD.
$       OES1G           STRESS          GRID POINTS     MAT. COORD.
$       OES1A           STRAIN/CURV.    ELT. CENTER     ELT. COORD.     DIAG 23
$       OES1AM          STRAIN/CURV.    ELT. CENTER     MAT. COORD.     DIAG 23
$       OES1AG          STRAIN/CURV.    GRID POINTS     MAT. COORD.     DIAG 23
$
ALTER 121
CURV OES1 ,MPT,CSTM,EST,SIL,GPL / OES1M,OES1G /
     C,Y,OUTOPT / C,Y,GC / C,Y,NINTPTS $
OFP OES1M,OES1G,,,, // V,N,CARDNO $
SAVE CARDNO $
$
$               GENERATE STRAIN OUTPUT.
$
PARAM // C,N,SSST / C,N,+23 $ TURN DIAG 23 ON.
SDR2 CASECC CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDT,,,UGV,EST, /
                     ,,,OES1A,, / C,N,STATICS $
PARAM // C,N,SSST / C,N,-23 $ TURN DIAG 23 OFF.
OFP OES1A,,,,, // V,N,CARDNO $
SAVE CARDNO $
PARAM // C,N,SSST / C,N,+23 $ TURN DIAG 23 ON.
CURV OES1A,MPT,CSTM,EST,SIL,GPL / OES1AM,OES1AG /
     C,Y,OUTOPT / C,Y,GC / C,Y,NINTPTS $
PARAM // C,N,SSST / C,N,-23 $ TURN DIAG 23 OFF.
OFP OES1AM,OES1AG,,,, // V,N,CARDNO $
SAVE CARDNO $
ENDALTER
CEND
TITLE = TEST OF TRIA1, TRIA2, QUAD1, AND QUAD2 STRAIN OPTION
SUBTITLE = EC-296 LEWIS RESEARCH CENTER          TESTB
LABEL = SIMPLE TEST OF CURV MODULE.
ECHO = UNSORT
SPC = 111
TEMP(LOAD) = 99
$
OUTPUT
SET 2 = 101 THRU 106
SET 3 = 103 THRU 108
OLOAD=ALL
DISP=ALL
SPCF=ALL
FORCE=ALL
$
SUBCASE 10
LOAD = 732
STRESSES = ALL
REPCASE 11
STRESSES(PUNCH) = 2
REPCASE 12
```

```
STRESSES(PRINT,PUNCH) = 3
$
BEGIN BULK
$
CONM2   1001    0       0.0     0.0     0.0     0.0     0.0     1.0     +C1001
+C1001  0.0     1.0     0.0
CONM2   1002    1001    0.0     0.0     0.0     10.0    0.0     0.0     +C1002
+C1002  12.0    -30.0   0.0
CONM2   1003    1002    0.0     0.0     0.0     1.0     0.0     0.0     +C1003
+C1003  0.0     0.0     1.0
$
CRDSET          1001                            1002    4
GRID    11              0.0     0.0     -5.0
GRID    12              0.0     0.0     0.0
GRID    13              0.0     0.0     +5.0
GRID    21              4.0     0.0     -5.0
GRID    22              4.0     0.0     0.0
GRID    23              4.0     0.0     +5.0
GRID    31              8.0     0.0     -5.0
GRID    32              8.0     0.0     0.0
GRID    33              8.0     0.0     +5.0
GRID    41              12.0    0.0     -5.0
GRID    42              12.0    0.0     0.0
GRID    43              12.0    0.0     +5.0
$
CQUAD2  101     100     11      21      22      12
CQUAD1  102     100     22      23      13      12
CTRIA2  103     100     22      21      31
CTRIA1  104     100     31      32      22
CTRIA2  105     100     22      32      33
CTRIA1  106     100     33      23      22
CQUAD1  107     100     42      32      31      41
CQUAD2  108     100     33      32      42      43
$
PQUAD1  100     771     1.2     771     0.144   771     1.2             +PQ1
+PQ1    -0.6    +0.6
PTRIA1  100     771     1.2     771     0.144   771     1.2             +PT1
+PT1    -0.6    +0.6
PQUAD2  100     771     1.2
PTRIA2  100     771     1.2
$
MAT1    771     12.0+6          0.2             2.0-8   100.0           +M771
+M771                           1003
$
TEMPD   99      300.0
$
SPC1    111     123456  11      12      13      21      23      31      +S111
+S111   33      41      42      43
$
PLOAD2  333     25.0    101     THRU    108
FORCE1  333     22      250.0   22      12
FORCE1  333     32      250.0   32      42
$
PARAM   NINTPTS 4
$
ENDDATA
```

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Notes

Card Nos.	Description
15 - 19	Generate and output stresses in the material coordinate system (ØES1M) and interpolate to the grid points (ØES1G).
23	Turn on DIAG 23 so that all requests for STRESS will be treated as if they were calling for strain/curvatures.
24 - 25	Compute element strains (ØES1A).
26	Turn off DIAG 23.
27 - 28	Output element strains.
29	Turn on DIAG 23.
30 - 31	Generate element strain/curvatures in the material coordinate system (ØES1AM) and interpolate to the grid points (ØES1AG).
32	Turn off DIAG 23.
33 - 34	Output element strain/curvature data.
47 - 50	Global output requests which apply to all subcases.
54	Request for all "stresses." Due to the nature of the DMAP alters, all of the items listed below will be printed as a result of this card. 1. element stresses in the individual element coordinate systems. 2. element stresses in the material coordinate system 3. grid point stresses in the material coordinate system. 4. element strain/curvatures in the individual element coordinate systems. 5. element strain/curvatures in the material coordinate system. 6. grid point strain/curvatures in the material coordinate system.
56	Request for "stresses" for the elements (and connecting grid points) in set 2 to be punched. See card 54 description.
58	Request for "stresses" for the elements (and connecting grid points) in set 3 to be printed and punched. See card 54 description.
100	Defines coordinate system 1003 to be the material coordinate system associated with material 771.
111	Defines the number of "closest" independent points to be used in interpolating to each dependent point. Used in the CURV DMAP instruction (see cards 17 and 31).

TEST OF TRIA1, TRIA2, QUAD1, AND QUAD2 STRAIN OPTION — MARCH 6, 1975 — NASTRAN 3/ 5/75 — PAGE 13
EC-296 LEWIS RESEARCH CENTER — TESTB

SIMPLE TEST OF CURV MODULE. — SUBCASE 10

S T R E S S E S   I N   G E N E R A L   T R I A N G U L A R   E L E M E N T S   (C T R I A 1)

ELEMENT ID.	FIBRE DISTANCE	NORMAL-X	NORMAL-Y	SHEAR-XY	ANGLE	MAJOR	MINOR	MAX SHEAR
104	.0	1.244672-25	1.898254-06	-7.593014-07	-79.0993	1.971368-06	-7.311405-08	2.044482-06
	-1.000000+00	-9.298223-06	-9.368640-06	5.589408-06	44.6391	-6.538518-06	-1.212835-05	5.585044-06
106	.0	.0	-9.476478-26	7.593015-07	45.0000	3.796507-07	-3.796507-07	7.593015-07
	-1.000000+00	-2.591438-06	1.047867-05	-6.947539-06	-75.9211	1.134985-0.	-3.372625-06	1.472248-05

TEST OF TRIA1, TRIA2, QUAD1, AND QUAD2 STRAIN OPTION — MARCH 6, 1975 — NASTRAN 3/ 5/75 — PAGE 14
EC-296 LEWIS RESEARCH CENTER — TESTB

SIMPLE TEST OF CURV MODULE. — SUBCASE 10

S T R E S S E S   I N   G E N E R A L   T R I A N G U L A R   E L E M E N T S   (C T R I A 2)

ELEMENT ID.	FIBRE DISTANCE	NORMAL-X	NORMAL-Y	SHEAR-XY	ANGLE	MAJOR	MINOR	MAX SHEAR
103	.0	9.476478-26	.0	7.593015-07	45.0000	3.796507-07	-3.796507-07	7.593015-07
	-1.000000+00	1.047867-05	-2.501441-06	-6.947541-06	-14.0789	1.134985-05	-3.372626-06	1.472248-05
105	.0	1.898254-06	-1.244672-25	-7.593014-07	-10.9007	1.971368-06	-7.311405-08	2.044482-06
	-1.000000+00	-9.368644-06	-9.298225-06	5.589358-06	45.3609	-6.538514-06	-1.212836-05	5.585042-06

TEST OF TRIA1, TRIA2, QUAD1, AND QUAD2 STRAIN OPTION — MARCH 6, 1975 — NASTRAN 3/ 5/75 — PAGE 15
EC-296 LEWIS RESEARCH CENTER — TESTB

SIMPLE TEST OF CURV MODULE. — SUBCASE 10

S T R E S S E S   I N   G E N E R A L   Q U A D R I L A T E R A L   E L E M E N T S   (C Q L A D 2)

ELEMENT ID.	FIBRE DISTANCE	NORMAL-X	NORMAL-Y	SHEAR-XY	ANGLE	MAJOR	MINOR	MAX SHEAR
101	.0	-4.745634-07	4.738239-26	-3.796507-07	-70.6701	6.658714-08	-5.411586-07	6.077377-07
	-1.000000+00	4.116985-06	-3.320355-13	3.134401-05	41.2586	1.786511-05	-1.374813-05	3.161324-05
108	.0	-6.223359-26	-4.745634-07	3.796507-07	19.3299	6.658714-08	-5.411585-07	6.077377-07
	-1.000000+00	-1.770333-13	3.300213-06	-2.689749-05	-48.6034	1.480266-05	-1.152265-05	2.632531-05

TEST OF TRIA1, TRIA2, QUAD1, AND QUAD2 STRAIN OPTION — MARCH 6, 1975 — NASTRAN 3/ 5/75 — PAGE 16
EC-296 LEWIS RESEARCH CENTER — TESTB

SIMPLE TEST OF CURV MODULE. — SUBCASE 10

S T R E S S E S   I N   G E N E R A L   Q U A D R I L A T E R A L   E L E M E N T S   (C Q L A D 1)

ELEMENT ID.	FIBRE DISTANCE	NORMAL-X	NORMAL-Y	SHEAR-XY	ANGLE	MAJOR	MINOR	MAX SHEAR
102	.0	-4.738239-26	-4.745634-07	-3.796507-07	-19.3299	6.658714-08	-5.411586-07	6.077377-07
	-1.000000+00	1.352137-13	4.116986-06	3.134401-05	48.7414	1.786511-05	-1.374813-05	3.161324-05
107	.0	-4.745634-07	6.223359-26	3.796507-07	70.6701	6.658714-08	-5.411585-07	6.077377-07
	-1.000000+00	3.300614-06	1.221233-13	-2.689749-05	-41.3966	1.480266-05	-1.152265-05	2.632531-05

Sample Problem

Grid Point Strain/Curvatures in Material Coordinates

TEST OF TRIA1, TRIA2, QUAD1, AND QUAD2 STRAIN OPTION MARCH 6, 1975 NASTRAN 3/ 5/75 PAGE 21
EC-296 LEWIS RESEARCH CENTER TEST8

SIMPLE TEST OF CURV MODULE. SUBCASE 10

S T R E S S E S   I N   G E N E R A L   T R I A N G U L A R   E L E M E N T S   (C T R I A 1)

ELEMENT ID.	FIBRE DISTANCE	STRESSES IN ELEMENT COORD SYSTEM NORMAL-X	NORMAL-Y	SHEAR-XY	PRINCIPAL STRESSES (ZERO SHEAR) ANGLE	MAJOR	MINOR	MAX SHEAR
104	1.000000+03	1.898254-06	1.244672-25	7.593014-07	10.9087	1.971368-06	-7.211405-08	2.044482-05
	1.000000+00	-9.360640-06	-9.298223-06	-5.589400-06	-45.3689	-6.538518-06	-1.212835-05	5.085044-06
106	1.000000+03	.0	-9.476478-26	7.593015-07	45.0000	3.796507-07	-3.796507-07	7.593015-08
	1.000000+00	-2.591438-06	1.047867-05	-6.947539-06	-75.9211	1.134985-05	-3.372625-06	1.472248-05

TEST OF TRIA1, TRIA2, QUAD1, AND QUAD2 STRAIN OPTION MARCH 6, 1975 NASTRAN 3/ 5/75 PAGE 22
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SIMPLE TEST OF CURV MODULE. SUBCASE 10

S T R E S S E S   I N   G E N E R A L   T R I A N G U L A R   E L E M E N T S   (C T R I A 2)

ELEMENT ID.	FIBRE DISTANCE	STRESSES IN ELEMENT COORD SYSTEM NORMAL-X	NORMAL-Y	SHEAR-XY	PRINCIPAL STRESSES (ZERO SHEAR) ANGLE	MAJOR	MINOR	MAX SHEAR
103	1.000000+03	.0	9.476478-26	-7.593015-07	-45.0000	3.796507-07	-3.796507-07	7.593015-08
	1.000000+00	-2.591441-06	1.047867-05	6.947541-06	75.9211	1.134585-05	-3.372625-06	1.472248-05
105	1.000000+03	1.898254-06	-1.244672-25	-7.593014-07	-10.9087	1.971368-08	-7.211405-08	2.044482-05
	1.000000+00	-9.368644-06	-9.298225-06	5.589398-06	45.3689	-6.538514-06	-1.212836-05	5.085842-06

TEST OF TRIA1, TRIA2, QUAD1, AND QUAD2 STRAIN OPTION MARCH 6, 1975 NASTRAN 3/ 5/75 PAGE 23
EC-296 LEWIS RESEARCH CENTER TEST8

SIMPLE TEST OF CURV MODULE. SUBCASE 10

S T R E S S E S   I N   G E N E R A L   Q U A D R I L A T E R A L   E L E M E N T S   (C Q U A D 2)

ELEMENT ID.	FIBRE DISTANCE	STRESSES IN ELEMENT COORD SYSTEM NORMAL-X	NORMAL-Y	SHEAR-XY	PRINCIPAL STRESSES (ZERO SHEAR) ANGLE	MAJOR	MINOR	MAX SHEAR
101	1.000000+03	-4.745834-07	4.738239-26	-3.796507-07	-78.6781	6.658714-08	-8.411506-07	6.277377-06
	1.000000+00	4.116985-06	-3.320355-13	3.134481-05	41.2586	1.786511-05	-1.374813-05	3.161324-05
108	1.000000+03	-4.745634-07	-6.223359-26	-3.796507-07	-78.6781	6.658714-08	-8.411505-07	6.277377-06
	1.000000+00	3.390813-06	-1.770333-13	2.609749-05	41.3966	1.488266-05	-1.150268-05	2.638531-05

TEST OF TRIA1, TRIA2, QUAD1, AND QUAD2 STRAIN OPTION MARCH 6, 1975 NASTRAN 3/ 5/75 PAGE 24
EC-296 LEWIS RESEARCH CENTER TEST8

SIMPLE TEST OF CURV MODULE. SUBCASE 10

S T R E S S E S   I N   G E N E R A L   Q U A D R I L A T E R A L   E L E M E N T S   (C Q U A D 1)

ELEMENT ID.	FIBRE DISTANCE	STRESSES IN ELEMENT COORD SYSTEM NORMAL-X	NORMAL-Y	SHEAR-XY	PRINCIPAL STRESSES (ZERO SHEAR) ANGLE	MAJOR	MINOR	MAX SHEAR
102	1.000000+03	-4.745634-07	-4.738239-26	3.796507-07	78.6781	6.658714-08	-8.411506-07	6.277377-06
	1.000000+00	4.116986-06	1.352137-13	-3.134481-05	-41.2586	1.786511-05	-1.374813-05	3.161324-05
107	1.000000+03	-4.745634-07	6.223359-26	3.796507-07	78.6781	6.658714-08	-8.411505-07	6.277377-06
	1.000000+00	3.390814-06	1.221233-13	-2.609749-05	-41.3966	1.488266-05	-1.150268-05	2.638531-05

TEST OF TRIA1, TRIA2, QUAD1, AND QUAD2 STRAIN OPTION   MARCH 6, 1975   NASTRAN 3/ 5/75   PAGE 28
EC-256 LEWIS RESEARCH CENTER   TESTB

SIMPLE TEST OF CURV MODULE.   SUBCASE 10

S T R E S S E S   I N   G E N E R A L   T R I A N G U L A R   E L E M E N T S   (C T R I A 1)

ELEMENT ID.	FIBRE DISTANCE	STRESSES IN ELEMENT COORD SYSTEM NORMAL-X	NORMAL-Y	SHEAR-XY	PRINCIPAL STRESSES (ZERO SHEAR) ANGLE	MAJOR	MINOR	MAX SHEAR
11	1.893999+03	-2.286670-06	3.231275-26	-1.829343-06	-70.6781	3.288494-07	-2.667528-06	2.528377-06
	4.399999+01	1.196067-05	1.514110-05	6.366077-05	46.4749	4.537350-05	-1.827173-05	6.374924-05
12	1.893999+03	-8.492314-07	1.155558-33	7.549517-15	90.0000	.0	-8.492314-07	8.492314-07
	6.399999+01	8.310167-06	-5.025529-06	2.859935-13	.0000	8.310167-06	-5.025529-06	1.333570-05
13	1.893999+03	-2.286670-06	-3.231275-26	1.829343-06	70.6781	3.288494-07	-2.607528-06	2.528377-06
	4.399999+01	1.186062-05	1.514110-05	-6.366077-05	-46.4749	4.537350-05	-1.827173-05	6.374923-05
21	1.893999+03	-1.769695-06	1.068005-25	-1.271175-06	-72.1551	2.846141-07	-1.574305-06	2.178923-06
	5.399999+01	6.362098-06	2.068596-05	1.651970-05	65.4639	2.445640-05	-2.551585-06	2.186489-05
22	1.893999+03	8.416246-07	1.348151-33	2.664535-14	.0000	8.416246-07	.0	8.416246-07
	6.399999+01	-2.481769-06	-8.183505-06	-6.323830-13	-.0000	-2.481769-06	-8.183505-06	5.701744-06
23	1.893999+03	-1.769695-06	-1.068005-25	1.271175-06	72.1551	2.846141-07	-1.574305-06	2.178923-06
	5.399999+01	6.362104-06	2.068597-05	-1.651969-05	-65.4639	2.445640-05	2.551592-06	2.186489-05
31	1.893999+03	-1.671254-06	1.277544-25	-6.250290-07	-79.7474	5.652646-08	-1.727780-06	1.784306-06
	5.399999+01	6.045781-06	1.817947-05	-1.387383-05	-66.4320	2.183182-05	3.154223-06	1.783680-05
32	1.893999+03	9.491260-07	-1.540744-33	-8.881784-15	-.0000	9.491268-07	.0	9.491268-07
	4.399999+01	-4.301180-06	-5.578934-06	-5.115908-13	-.0000	-4.301180-06	-5.578934-06	1.277755-06
33	1.893999+03	-1.671254-06	-1.277544-25	6.258289-07	79.7474	5.652646-08	-1.727788-06	1.784306-06
	5.399999+01	6.045785-06	1.817947-05	1.387384-05	66.4320	2.183183-05	3.154225-06	1.783680-05
41	1.893999+03	-3.019551-06	9.911843-26	7.799342-08	89.2682	5.835332-10	-3.022555-06	3.022558-06
	5.399999+01	1.560100-05	1.483172-05	-4.002416-05	-44.4494	3.523218-05	-4.759375-06	4.003156-05
42	1.893999+03	-1.898254-06	-1.925930-33	-1.243450-14	-90.0000	.0	-1.898254-06	1.898254-06
	4.399999+01	1.090121-05	5.578935-06	1.066025-12	.0000	1.090121-05	5.578535-06	5.322273-06
43	1.893999+03	-3.019551-06	-9.911843-26	-7.799343-08	-89.2682	5.835332-10	-3.022555-06	3.022558-06
	5.399999+01	1.560100-05	1.483172-05	4.002417-05	44.4494	3.523218-05	-4.759380-06	4.003156-05

Grid Point Strain/Curvatures in Material Coordinates

ORIGINAL PAGE IS OF POOR QUALITY

Sample Problem

Punch Output for Grid Point Strain/Curvatures in Material Coordinates

```
283.  ELEMENT STRESSES                                                                  283
284.  REAL OUTPUT                                                                       284
285.  SUBCASE ID =          12                                                          285
286.  ELEMENT TYPE =        19                                                          286
287.          107           1.003000+03      -4.745634-07       6.223359-26             287
288.  -CONT-                3.796507-07       7.067010+01       6.658714-08             288
289.  -CONT-               -5.411555-07       6.077377-06       1.000000+00             289
290.  -CONT-                3.320014-06       1.221233-13      -2.609745-05             290
291.  -CONT-               -4.139661+01       1.480266-05      -1.150265-05             291
292.  -CONT-                2.630531-05                                                 292
293.  TITLE    = TEST OF TRIA1, TRIA2, QUAD1, AND QUAD2 STRAIN OPTION                   293
294.                                                                                    294
295.  SUBTITLE = EC-296 LEWIS RESEARCH CENTER          TESTB                            295
296.                                                                                    296
297.  LABEL    = SIMPLE TEST OF CURV MODULE:                                            297
298.                                          REFCASE 12                                298
299.  ELEMENT STRESSES                                                                  299
300.  REAL OUTPUT                                                                       300
301.  SUBCASE ID =          12                                                          301
302.  ELEMENT TYPE =        6                                                           302
303.          21            1.003000+03      -1.344377-06       1.047363-25             303
304.  -CONT-               -1.775723-06      -6.356445+01       4.414251-07             304
305.  -CONT-               -1.785802-06       2.227227-06       4.300000+01             305
306.  -CONT-                2.044211-06       2.563584-05       1.733677-05             306
307.  -CONT-                7.187295+01       2.852284-05      -7.935847-07             307
308.  -CONT-                2.931642-05                                                 308
309.          22            1.003000+03      -1.858254-06       2.311116-33             309
310.  -CONT-                6.354885-14       9.020000+01       0.000000                310
311.  -CONT-               -1.858254-26       1.858254-06       4.300000+01             311
312.  -CONT-                4.365764-06       3.026555-05       2.614797-12             312
313.  -CONT-                9.000000+01       3.026555-05       4.365764-06             313
314.  -CONT-                2.528575-05                                                 314
315.          23            1.003000+03      -1.344377-06      -1.047363-25             315
316.  -CONT-                1.775723-06       6.356445+01       4.414251-07             316
317.  -CONT-               -1.785802-06       2.227227-06       4.300000+01             317
318.  -CONT-                2.044210-06       2.563584-05      -1.733677-05             318
319.  -CONT-               -7.187295+01       2.852284-05      -7.935760-07             319
320.  -CONT-                2.931641-05                                                 320
321.          31            1.003000+03      -4.490443-07       1.754262-25             321
322.  -CONT-                4.134558-07       6.868140+01       8.067715-08             322
323.  -CONT-               -5.297215-07       6.103986-07       5.300000+01             323
324.  -CONT-                1.559191-06       5.958575-06      -2.526851-05             324
325.  -CONT-               -4.993825+01       1.658320-05      -9.865431-06             325
326.  -CONT-                2.564863-05                                                 326
327.          32            1.003000+03       9.451268-07      -2.503705-33             327
328.  -CONT-               -1.421085-14      -4.289322-07       9.491268-07             328
329.  -CONT-                0.000000          9.451268-07       4.300000+01             329
330.  -CONT-               -4.321100-06      -5.578934-06      -5.115908-13             330
331.  -CONT-               -1.147212-05      -4.321100-06      -5.578934-06             331
332.  -CONT-                1.277755-06                                                 332
333.          33            1.003000+03      -4.490442-07      -1.754262-25             333
334.  -CONT-               -4.134550-07      -6.868140+01       8.067717-08             334
335.  -CONT-               -5.297213-07       6.103985-07       5.300000+01             335
336.  -CONT-                1.559105-06       5.958574-06       2.526851-05             336
337.  -CONT-                4.993825+01       1.658320-05      -9.865433-06             337
338.  -CONT-                2.564863-05                                                 338
339.          41            1.003000+03      -2.483614-06       1.323054-25             339
```

Appendix B

DMAP ALTER PACKETS

Several modes of operation of using this new capability are possible. Some of these are listed below and described separately in the sections which follow. Combinations of the various modes of operation are possible. The data requirements are combinations of the ones presented and can be deduced from the examples given in the text.

Element Output In Element Reference	A1	Standard Stress Output
	A2	Generate strain/curvatures in place of stresses
	A3	Generate strain/curvatures in addition to stresses
Element Output In Material Reference	B1	Generate stresses in material coordinates
	B2	Generate strain/curvatures in material coordinates
	B3	Generate both strain/curvatures and stresses in material coordinates
Grid Output In Material Reference	C1	Generate stresses at grid points (measured in material coordinates)
	C2	Generate strain/curvatures at grid points (measured in material coordinates)
	C3	Generate both strain/curvatures and stresses at grid points (measured in material coordinates)
Element Output In Both Element & Material Reference (combination of A&B)	D1	Generate stresses in both element and material coordinates
	D2	Generate strain/curvatures in both element and material coordinates
	D3	Generate both strain/curvatures and stresses in both element and material coordinates
Both Element & Grid Output in Material Reference (combination of B&C)	E1	Generate stresses at both element and grid point locations (measured in material coordinates)
	E2	Generate strain/curvatures at both element and grid point locations (measured in material coordinates)
	E3	Generate both strain/curvatures and stresses at both element and grid point locations (measured in material coordinates)

Detailed data deck requirements will now be given for the modes of operation just enumerated. The standard output will be called option A1 and need not be described in detail.

A2. To produce strain/curvature output instead of stress output for elements:

Executive Control Deck: Turn on DIAG 23.

Case Control Deck: Select desired elements via STRESS=request.

Bulk Data Deck: None

Remarks: Only QUAD1, QUAD2, TRIA1 and TRIA2 elements will generate strain/curvature output. Other elements will generate the usual stress values.

A3. To produce both stress output and strain/curvature output for elements:

Executive Control Deck:

```
ALTER    121
PARAM     // C,N,SSST / C,N,+23 $ TURN DIAG 23 ØN
SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDT,,,UGV,EST, /
          ,,,ØES1A,, / C,N,STATICS $
ØFP      ØES1A,,,,, // V,N,CARDNØ $
SAVE     CARDNØ $
PARAM    //C,N,SSST/C,N,-23 $ TURN DIAG 23 ØFF
ENDALTER
```

Case Control Deck: Select desired elements via STRESS=request.

Bulk Data Deck: None

Remarks: 1. Only QUAD1, QUAD2, TRIA1 and TRIA2 elements will generate strain/curvature output. Other elements will generate the usual stress values in both sets of output.

2. The same elements will appear in both the stress and strain/curvature output.

B1. To produce stress output measured in material coordinates:

Executive Control Deck:

```
ALTER     120,120
ØFP       ØUGV1,ØPG1,ØQG1,ØEF1,, // V,N,CARDNØ $
ALTER     121
CURV      ØES1,MPT,CSTM,EST,, / ØES1M, / C,Y,ØUTØPT=0 / C,N,1 $
ØFP       ØES1M,,,,, // V,N,CARDNØ $
SAVE      CARDNØ $
ENDALTER
```

Case Control Deck: Select desired elements via STRESS=request.

Bulk Data Deck:

1. The material coordinate system identification number must be coded on the MAT1 or MAT2 card for any element whose stress is to be measured in material coordinates.
2. PARAM ØUTØPT (optional) may be used to select ØFP output device. See module DMAP description for details.

Remarks:

1. Only QUAD1, QUAD2, TRIA1 and TRIA2 elements will appear in the stress output.
2. A default basic material coordinate system is not provided. For this case, set up a rectangular system coincident with the basic system.

B2. To produce strain/curvature output measured in material coordinates:

Executive Control Deck:

1. DIAG 23
2. ALTER 120,120

```
ØFP      ØUGV1,ØPG1,ØQG1,ØEF1,, // V,N,CARDNØ $
ALTER    121
CURV     ØES1,MPT,CSTM,EST,, / ØES1M, /C,Y,ØUTØPT=0 / C,N,1 $
ØFP      ØES1M,,,,, // V,N,CARDNØ $
SAVE     CARDNØ $
ENDALTER
```

Case Control Deck: Select desired elements via STRESS=request.

Bulk Data Deck:

1. The material coordinate system identification number must be coded on the MAT1 or MAT2 card for any element whose stress is to be measured in material coordinates.
2. PARAM ØUTØPT (optional) may be used to select ØFP output device. See module DMAP description for details.

Remarks:

1. Only QUAD1, QUAD2, TRIA1 and TRIA2 elements will appear in the strain/curvature output.
2. A default basic material coordinate system is not provided. For this case, set up a rectangular system coincident with the basic system.

B3. To produce both stress and strain/curvature output measured in material coordinates.

Executive Control Deck:

```
ALTER    120,120
ØFP      ØUGV1,ØPG1,ØQG1,ØEF1,, // V,N,CARDNØ $
ALTER    121
CURV     ØES1,MPT,CSTM,EST,, / ØES1M, / C,Y,ØUTØPT=0 / C,N,1 $
ØFP      ØES1M,,,,, // V,N,CARDNØ $
SAVE     CARDNØ $
PARAM    // C,N,SSST / C,N,+23 $ TURN DIAG 23 ØN
SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDT,,,UGV,EST, /
           ,,,ØES1A,, / C,N,STATICS $
CURV     ØES1A,MPT,CSTM,EST,, / ØES1AM, / C,Y,ØUTØPT=0 / C,N,1 $
ØFP      ØES1AM,,,,, // V,N,CARDNØ $
SAVE     CARDNØ $
PARAM    // C,N,SSST / C,N,-23 $ TURN DIAG 23 ØFF
ENDALTER
```

Case Control Deck: Select desired elements via STRESS=request.

Bulk Data Deck:

1. The material coordinate system identification number must be coded on the MAT1 or MAT2 card for any element whose stress and strain/curvature is to be measured in material coordinates.
2. PARAM ØUTØPT (optional) may be used to select ØFP output device. See module DMAP description for details.

Remarks:

1. Only QUAD1, QUAD2, TRIA1 and TRIA2 elements will appear in the stress and strain/curvature output.
2. A default basic material coordinate system is not provided. For this case, set up a rectangular system coincident with the basic system.
3. The same elements will appear in both the stress and strain/curvature output.

C1. To produce stress output at grid points (measured in material coordinates):

Executive Control Deck:

```
ALTER     120,120
ØFP       ØUGV1,ØPG1,ØQG1,ØEF1,, // V,N,CARDNØ $
ALTER     121
CURV      ØES1,MPT,CSTM,EST,SIL,GPL / ØES1M,ØES1G / C,Y,ØUTØPT=0 $
ØFP       ØES1G,,,,, // V,N,CARDNØ $
SAVE      CARDNØ $
ENDALTER
```

Case Control Deck: Select desired elements via STRESS=request.

Bulk Data Deck:

1. The material coordinate system identification number must be coded on the MAT1 or MAT2 card for any element whose stress is to be measured in material coordinates.
2. PARAM ØUTØPT (optional) may be used to select ØFP output device. See module DMAP description for details.

Remarks:

1. Only grid points connecting QUAD1, QUAD2, TRIA1 and TRIA2 elements will appear in the ØES1G output.
2. A default basic material coordinate system is not provided. For this case, set up a rectangular system coincident with the basic system.
3. A working core of approximately $3N_1^2N_2^2$ words (where N_1 and N_2 are the number of cells per side of a rectangular mesh) must be available to carry out the interpolation to the grid points for such a mesh. Subdivision of the surface mesh into sub-meshes may be necessary for large problems.

C2. To produce strain/curvature output at grid points (measured in material coordinates):

Executive Control Deck:

1. DIAG 23
2. ALTER 120,120

```
ØFP      ØUGV1,ØPG1,ØQG1,ØEF1,, // V,N,CARDNØ $
ALTER    121
CURV     ØES1,MPT,CSTM,EST,SIL,GPL / ØES1M,ØES1G / C,Y,ØUTØPT=0 $
ØFP      ØES1G,,,,, // V,N,CARDNØ $
SAVE     CARDNØ $
ENDALTER
```

Case Control Deck: Select desired elements via STRESS=request.

Bulk Data Deck:

1. The material coordinate system identification number must be coded on the MAT1 or MAT2 card for any element whose strain/curvature is to be measured in material coordinates.
2. PARAM ØUTØPT (optional) may be used to select ØFP output device. See module DMAP description for details.

Remarks:

1. Only grid points connecting QUAD1, QUAD2, TRIA1 and TRIA2 elements will appear in the ØES1G output.
2. A default basic material coordinate system is not provided. For this case, set up a rectangular system coincident with the basic system.
3. A working core of approximately $3N_1^2N_2^2$ words (where N_1 and N_2 are the number of cells per side of a rectangular mesh) must be available to

carry out the interpolation to the grid points for such a mesh. Subdivision of the surface mesh into sub-meshes may be necessary for large problems.

C3. To produce both strain/curvature and stress output at grid points (measured in material coordinates):

Executive Control Deck:

```
ALTER    120,120
ØFP      ØUGV1,ØPG1,ØQG1,ØEF1,, // V,N,CARDNØ $
ALTER    121
CURV     ØES1,MPT,CSTM,EST,SIL,GPL / ØES1M,ØES1G / C,Y,ØUTØPT=0 $
ØFP      ØES1G,,,,, // V,N,CARDNØ $
SAVE     CARDNØ $
PARAM    // C,N,SSST / C,N,+23 $ TURN DIAG 23 ØN
SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDT,,,UGV,EST, /
          ,,,ØES1A,, / C,N,STATICS $
CURV     ØES1A,MPT,CSTM,EST,SIL,GPL / ØES1AM,ØES1AG / C,Y,ØUTØPT=0 $
ØFP      ØES1AG,,,,, // V,N,CARDNØ $
SAVE     CARDNØ $
PARAM    // C,N,SSST / C,N,-23 $ TURN DIAG 23 ØFF
ENDALTER
```

Case Control Deck: Select desired elements via STRESS=request.

Bulk Data Deck:

1. The material coordinate system identification number must be coded on the MAT1 or MAT2 card for any element whose strain/curvature or stress is to be measured in material coordinates.
2. PARAM ØUTØPT (optional) may be used to select ØFP output device. See module DMAP description for details.

Remarks:

1. Only grid points connecting QUAD1, QUAD2, TRIA1 and TRIA2 elements will appear in the ØES1G and ØES1AG outputs.
2. A default basic material coordinate system is not provided. For this case, set up a rectangular system coincident with the basic system.
3. A working core of approximately $3N_1^2N_2^2$ words (where N_1 and N_2 are the number of cells per side of a rectangular mesh) must be available to carry out the interpolation to the grid points for such a mesh. Subdivision of the surface mesh into sub-meshes may be necessary for large problems.

D1. To produce stress output in both element and material coordinates:

Executive Control Deck:

```
ALTER     121
CURV      ØES1,MPT,CSTM,EST,, / ØES1M, / C,Y,ØUTØPT=0 / C,N,1 $
ØFP       ØES1M,,,,, // V,N,CARDNØ $
SAVE      CARDNØ $
ENDALTER
```

Case Control Deck: Select desired elements via STRESS=request.

Bulk Data Deck:

1. The material coordinate system identification number must be coded on the MAT1 or MAT2 card for any element whose stress is to be measured in material coordinates.
2. PARAM ØUTØPT (optional) may be used to select ØFP output device. See module DMAP description for details.

Remarks:

1. Only QUAD1, QUAD2, TRIA1 and TRIA2 elements will appear in the ØES1M output.
2. A default basic material coordinate system is not provided. For this case, set up a rectangular system coincident with the basic system.

D2. To produce strain/curvature output in both element and material coordinates:

Executive Control Deck:

1. DIAG 23
2. ALTER 121

```
CURV     ØES1,MPT,CSTM,EST,, / ØES1M, / C,Y,ØUTØPT=0 / C,N,1 $
ØFP      ØES1M,,,,, // V,N,CARDNØ $
SAVE     CARDNØ $
ENDALTER
```

Case Control Deck: Select desired elements via STRESS=request.

Bulk Data Deck:

1. The material coordinate system identification number must be coded on the MAT1 or MAT2 card for any element whose strain/curvature is to be measured in material coordinates.
2. PARAM ØUTØPT (optional) may be used to select ØFP output device. See module DMAP description for details.

Remarks:

1. Only QUAD1, QUAD2, TRIA1 and TRIA2 elements will appear in the ØES1M output.
2. A default basic material coordinate system is not provided. For this case, set up a rectangular system coincident with the basic system.

D3. To produce both strain/curvature and stress output in both element and material coordinates:

Executive Control Deck:

```
ALTER    121
CURV     ØES1,MPT,CSTM,EST,, / ØES1M, / C,Y,ØUTØPT=0 / C,N,1 $
ØFP      ØES1M,,,,, // V,N,CARDNØ $
SAVE     CARDNØ $
PARAM    // C,N,SSST / C,N,+23 $ TURN DIAG 23 ØN
SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDT,,,UGV,EST, /
          ,,,ØES1A,, / C,N,STATICS $
ØFP      ØES1A,,,,, // V,N,CARDNØ $
SAVE     CARDNØ $
CURV     ØES1A,MPT,CSTM,EST,, / ØES1AM, / C,Y,ØUTØPT=0 / C,N,1 $
ØFP      ØES1AM,,,,, // V,N,CARDNØ $
SAVE     CARDNØ $
PARAM    // C,N,SSST / C,N,-23 $ TURN DIAG 23 ØFF
ENDALTER
```

Case Control Deck: Select desired elements via STRESS=request.

Bulk Data Deck:

1. The material coordinate system identification number must be coded on the MAT1 or MAT2 card for any element whose strain/curvature (or stress) is to be measured in material coordinates.
2. PARAM ØUTØPT (optional) may be used to select ØFP output device. See module DMAP description for details.

Remarks:

1. The selected elements will all appear in the ØES1 and ØES1A output.
2. Only QUAD1, QUAD2, TRIA1 and TRIA2 elements will generate strain/curvature values in the ØES1A output. All other elements will generate the usual stress values in both sets of output.
3. Only QUAD1, QUAD2, TRIA1 and TRIA2 elements will appear in the ØES1M and ØES1AM output.

E1. To produce stress output at both elements and grid points (measured in material coordinates):

Executive Control Deck:

```
ALTER     120,120
ØFP       ØUGV1,ØPG1,ØQG1,ØEF1,, // V,N,CARDNØ $
ALTER     121
CURV      ØES1,MPT,CSTM,EST,SIL,GPL / ØES1M,ØES1G / C,Y,ØUTØPT=0 $
ØFP       ØES1M,ØES1G,,,, // V,N,CARDNØ $
SAVE      CARDNØ $
ENDALTER
```

Case Control Deck: Select desired elements via STRESS=request.

Bulk Data Deck:

1. The material coordinate system identification number must be coded on the MAT1 or MAT2 card for any element whose stress is to be measured in material coordinates.
2. PARAM ØUTØPT (optional) may be used to select ØFP output device. See module DMAP description for details.

Remarks:

1. Only QUAD1, QUAD2, TRIA1 and TRIA2 elements and grid points connecting them will appear in the stress output.
2. A default basic material coordinate system is not provided. For this case, set up a rectangular system coincident with the basic system.
3. A working core of approximately $3N_1^2N_2^2$ words (where N_1 and N_2 are the number of cells per side of a rectangular mesh) must be available to carry out the interpolation to the grid points of such a mesh. Subdivision of the surface mesh into sub-meshes may be necessary for large problems.

E2. To produce strain/curvature output at both elements and grid points (measured in material coordinates);

Executive Control Deck:

```
 1.  DIAG 23
 2.  ALTER     120,120
     ØFP       ØUGV1,ØPG1,ØQG1,ØEF1,, // V,N,CARDNØ $
     ALTER     121
     CURV      ØES1,MPT,CSTM,EST,SIL,GPL / ØES1M,ØES1G / C,Y,ØUTØPT=0 $
     ØFP       ØES1M,ØES1G,,,, // V,N,CARDNØ $
     SAVE      CARDNØ $
     ENDALTER
```

Case Control Deck: Select desired elements via STRESS=request.

Bulk Data Deck:

1. The material coordinate system identification number must be coded on the MAT1 or MAT2 card for any element whose strain/curvature is to be measured in material coordinates.
2. PARAM ØUTØPT (optional) may be used to select ØFP output device. See module DMAP description for details.

Remarks:

1. Only QUAD1, QUAD2, TRIA1 and TRIA2 elements and grid points connecting them will appear in the strain/curvature output.
2. A default basic material coordinate system is not provided. For this case, set up a rectangular system coincident with the basic system.

3. A working core of approximately $3N_1^2N_2^2$ words (where N_1 and N_2 are the number of cells per side of a rectangular mesh) must be available to carry out the interpolation to the grid points of such a mesh. Subdivision of the surface mesh into sub-meshes may be necessary for large problems.

E3. To produce both strain/curvature and stress output at both elements and grid points (measured in material coordinates):

Executive Control Deck:

```
ALTER     120,120
ØFP       ØUGV1,ØPG1,ØQG1,ØEF1,, // V,N,CARDNØ $
ALTER     121
CURV      ØES1,MPT,CSTM,EST,SIL,GPL / ØES1M,ØES1G / C,Y,ØUTØPT=0 $
ØFP       ØES1M,ØES1G,,,, // V,N,CARDNØ $
SAVE      CARDNØ $
PARAM     // C,N,SSST / C,N,+23 $ TURN DIAG 23 ØN
SDR2      CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDT,,,UGV,EST, /
           ,,,ØES1A,, / C,N,STATICS $
CURV      ØES1A,MPT,CSTM,EST,SIL,GPL / ØES1AM,ØES1AG / C,Y,ØUTØPT=0 $
ØFP       ØES1AM,ØES1AG,,,, // V,N,CARDNØ $
SAVE      CARDNØ $
PARAM     // C,N,SSST / C,N,-23 $ TURN DIAG 23 ØFF
ENDALTER
```

Case Control Deck: Select desired elements via STRESS=request.

Bulk Data Deck:

1. The material coordinate system identification number must be coded on the MAT1 or MAT2 card for any element whose strain/curvature and stress is to be measured in material coordinates.
2. PARAM ØUTØPT (optional) may be used to select ØFP output device. See module DMAP description for details.

Remarks:

1. Only QUAD1, QUAD2, TRIA1 and TRIA2 elements and grid points connecting them will appear in the strain/curvature and stress outputs.
2. A default basic material coordinate system is not provided. For this case, set up a rectangular system coincident with the basic system.
3. A working core of approximately $3N_1^2N_2^2$ words (where N_1 and N_2 are the number of cells per side of a rectangular mesh) must be available to carry out the interpolation to the grid points of such a mesh. Subdivision of the surface mesh into sub-meshes may be necessary for large problems.

Interface with External Post-Processing Programs

The strain/curvature (or stress) data generated by NASTRAN as a result of this new capability may be picked up by an external program in several ways. The simplest is to let ØFP generate punch card images via the case control request STRESS(PUNCH)=...

These card images may then be read by FØRTRAN formatted READ statements in the usual way.

An alternate way is to utilize the utility module ØUTPUT2 to create a FØRTRAN binary file which can be directly read by the post-processor program. Usage of the utility module ØUTPUT2 and the format of the FØRTRAN-readable files are contained in the standard NASTRAN documentation.